Tillage Systems for Production of Small-Grain Pasture

M. T. Bowman, P. A. Beck,* K. B. Watkins, M. M. Anders, M. S. Gadberry, K. S. Lusby, S. A. Gunter, and D. S. Hubbell

Production Agriculture

ABSTRACT

The objective of this study was to compare conventional tillage (CT), reduced tillage (RT), and no-till (NT) establishment of wheat (*Triticum aestivum* L.) and rye (*Secale cereale* L.) forage for stocker calves (*Bos taurus*). Animal performance was analyzed as a completely randomized design using the mixed procedure of SAS. In the 2002–2003 study, grazing-d ha^{-1} was greater (P < 0.01) for CT than RT, but NT did not differ (P = 0.08) from CT and RT, while gain ha^{-1} was not affected ($P \geq 0.42$) by tillage treatment. During 2003–2004, grazing-d ha^{-1} was identical for all pastures, but gain ha^{-1} of NT was greater (P = 0.05) than CT and RT. Grazing-d ha^{-1} was greater (P = 0.05) for NT than CT and RT in 2004–2005 and gain ha^{-1} tended to be greater (P = 0.10) for NT than CT and RT. During 2005–2006, grazing-d ha^{-1} of CT was greater (P = 0.03) than RT, but gain ha^{-1} did not differ ($P \geq 0.81$) among treatments. Establishment of small-grain pasture using NT and RT was as successful as CT when timely fall rains promoted small grain emergence and growth, while NT was superior to CT and RT when fall rains are delayed and soil water profile can be maintained by summer chemical fallow.

In the fall and early spring, small-grain pastures have been used extensively to improve net-farm income in the High Plains. This improved net income comes from the availability of high-quality forage at a time of year when it is usually scarce and the availability of weaned calves is at a seasonally low price. Coulibaly et al. (1996) stated that grazing stocker cattle on wheat pasture in Oklahoma is one of the most profitable cattle enterprises available to producers.

Although there are economic advantages, grazing programs using small-grain forage have faced several challenges. These include too much or too little precipitation causing delayed planting, poor growth, and muddy conditions. Establishment of small-grain crops has traditionally involved intensive tillage techniques. Increased costs of equipment, fuel, and labor have raised questions about whether CT methods of production are the best option. The USDA (2003) reported that most of today's cropland has lost at least one-third or more of its carbon since its conversion into cropland. Cole et al. (1997) reported that soil organic carbon can be increased by decreased fallow periods, use of winter cover crops, conservation tillage, and erosion control.

M.T. Bowman and M.S. Gadberry, Univ. of Arkansas Coop. Ext. Serv., Little Rock, AR 72204; P.A. Beck, Univ. of Arkansas Southwest Res. and Ext. Cent., Hope, AR 71801; K.B. Watkins and M.M. Anders, Univ. of Arkansas Rice Res. and Ext. Cent., Stuttgart, AR 72160; K.S. Lusby, Univ. of Arkansas, Dep. of Animal Sci., Fayetteville, AR 72701; S.A. Gunter, USDA Southern Plains Range Res. Stn., Woodward, OK 73801; and D.S. Hubbell, Univ. of Arkansas Livestock and Forestry Branch Stn., Batesville, AR 72501. Received 11 Apr. 2007. *Corresponding author (pbeck@uaex.edu).

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In the southeastern United States, areas used for grazing generally have shallow, erosive soils. Therefore, farmers are urged to adopt conservation-tillage systems such as NT and RT. No-tillage techniques can maintain soil moisture and improve seedling establishment when precipitation is lacking (Allen and Entz, 1994). Additionally, NT has been shown to be an economically sound alternative to CT because of reductions in labor, machinery, and fuel costs (Ribera et al., 2004; Gemtos et al., 1998). However, cattle producers are reluctant to assume conservation-tillage practices due to fears of reduced forage yields. A limited amount of research has been conducted on the differences of forage yields among tillage methods. Wiatrak et al. (2004) reported that wheat forage yields were lower for NT than CT during some years. Lower ryegrass forage yields have been documented for NT plots compared with CT plots (Lang, 1992; Cuomo and Blouin, 1997). However, NT methods can contribute to better forage utilization in muddy conditions due to higher soil strength at the surface (García-Préchac et al., 2004). The objective of this study was to quantify differences in animal performance, forage growth, and forage quality of small-grain forages established using CT, RT, and NT.

MATERIALS AND METHODS

Study Site

A preliminary study was initiated in the fall of 2002 and a subsequent long-term tillage system evaluation was initiated during the fall of 2003, on 24 ha at the University of Arkansas Livestock and Forestry Branch Station near Batesville, in northeast Arkansas. The study site consisted of Peridge silt loam soil (fine-silty, mixed, mesic Typic Paleudalfs), a deep well-drained upland soil with moderate fertility (Hoelscher and Laurent, 1982). For the 6 yr before 2002, the area had been managed under CT to produce small-grain forages for stocker

Abbreviations: ADF, acid detergent fiber; ADG, average daily gain; BW, body weight; CP, crude protein; CT, conventional tillage; IVOMD, in vitro organic matter disappearance; NDF, neutral detergent fiber; NT, no till; RT, reduced tillage.

cattle. In the current study, small-grain pasture was established using: (i) CT: seed sown into a prepared seedbed (ii) RT: a single pass with a light disk and seed was then broadcast; or (iii) NT: direct seeding into an undisturbed seedbed. Five replicates of each treatment were randomly allocated to 1.6-ha pastures within the study site before study initiation and tillage treatments remained in the same pastures in subsequent years.

Seedbed Preparation and Planting

Conventional tillage consisted of chisel plowing each treatment pasture two times followed by disking two times with a cutting disk to incorporate any plant material and fertilizer or lime into the soil. A finishing disk was used two times before planting.

No-till and RT pastures were prepared by applications of 1.4 kg a.i. ha^{-1} of glyphosate [N-(phosphonomethyl) glycine] (Roundup Original Max, Monsanto Co., St. Louis, MO) during the early summer for annual grass and weed control and before planting. In RT, pastures were established by disking once with a finishing disk to disturb the soil surface residue to a target of 50% residue cover at the time of seeding. A conventional fertilizer spreader was used to broadcast seed after disking and then harrowed once to cover the seed.

For the preliminary study in 2002, seed was sown in CT pastures using a pull-type drill (model 20X7B, Deere and Co., Moline IL) and NT pastures were sown with a 2.4-m NT drill (Tye Pasture Pleaser, AGCO Company, Duluth, GA) in 17.8-cm rows to a depth of approximately 2.5 cm. For the subsequent study beginning in 2003, NT and CT pastures were sown using a 3.7-m John Deere grain drill (model 750, Deere and Co., Moline, IL) in 17.8-cm rows to a depth of approximately 2.5 cm.

Pastures in all treatments were seeded during the first week of September with 68 kg ha^{-1} of cereal rye (cv. Wintergrazer 70, Pennington Seed Co., Madison, GA) and 68 kg ha^{-1} of soft red winter wheat (cv. Delta King 9027, Delta King Seed Co., McCory, AR). Seed of each species was blended in a Gehl Mix-All mixer (model 55, Gehl Company, West Bend, WI). After mixing, seed was removed from the mixer and reweighed before planting. Each pasture was individually soil tested and fertilized and limed to meet soil-test recommendations (Chapman, 1998). Average soil surface residue for NT, RT, and CT pastures was 82, 65, and 4%, respectively, at planting over the 4 yr.

Forage Measurements and Sampling

During the preliminary study, for the 2002–2003 growing season, forage mass and stocking rate decisions were based on visual estimates. During the 2003–2004, 2004–2005, and 2005–2006 grazing seasons, forage yields were estimated using a calibrated rising-plate meter with 20 sampling points per pasture (Michell and Large, 1983). Calibration samples were collected by clipping all forage within a single 0.25-m^2 frame in each pasture to a 2.5-cm stubble height with hand shears. Clipped forage was dried to a constant weight under forced air at 50°C. Dry weights of these clippings were used to relate forage mass (kg ha^{-1}) to plate height within each treatment using linear regression for forage mass prediction.

Forage samples collected to be representative of diets consumed by grazing steers were collected from all pastures at four times during the 2003–2004 grazing study and monthly during the 2004–2005 and 2005–2006 studies by clipping forage to mimic forage selected by grazing steers. Samples were dried to a constant weight at 50°C under forced air. Dried samples were ground though a 1-mm screen in a Wiley Mill (Arthur H. Thomas, Philadelphia, PA). Samples were analyzed for dry matter (DM) and organic matter (Association of Official Analytical Chemists, 1990). Concentrations of N in each forage sample were determined by rapid combustion (850°C), conversion of all N-combustion products to N_2, and subsequent measurement by thermoconductivity cell (LECO model FP-428; LECO Corp., St. Joseph, MI). Crude protein (CP) was calculated as the percentage of N in the sample multiplied by 6.25. Analyses for neutral detergent fiber (NDF), acid detergent fiber (ADF), and in vitro OM disappearance (IVOMD) were conducted using the batch procedures outlined by ANKOM Technology Corporation (Fairport, NY). Sodium sulfite and heat-stable A-amylase were not included in the NDF solution. Ruminal fluid for IVOMD analysis was obtained from two ruminally-cannulated steers that were offered a diet of 85% alfalfa hay and 15% concentrate (as-is basis: 91.0% cracked corn, 4.0% liquid molasses, 5.0% trace mineral salt) at 2.0% body weight (BW) daily (as-fed basis). The steers were adapted to the diet for a minimum of 7 d before collecting ruminal fluid. Concentrations of ash were determined by combusting 2-g samples at 500°C for 8 h in a muffle furnace. All determination of DM performed in conjunction with the laboratory procedures described above were accomplished by drying the forage or fiber residue overnight at 100°C.

Animal Management

All animal procedures in the following experiment were conducted in accordance with the recommendations of Consortium (1988) and were approved by the University of Arkansas Institutional Animal Care and Use Committee.

All steers placed on each study were crossbred (English × Continental) calves and stratified by weight and breed characteristics to each of the three tillage treatments. Pastures were stocked when forage height reached 20 cm and were removed when forage mass (end of winter grazing period) or forage quality (end of spring grazing period) limited performance. Steers were preconditioned for 42-d before turnout and implanted with 40 mg trenbolone acetate and 8 mg estradial (Revalor–G, Intervet Inc., Millsboro, DE). Individual steer BW was recorded at the initiation and termination of grazing following a 16-h withdrawal period from feed and water.

The initial stocking and removal dates and grazing days for each grazing season are summarized in Table 1. During 2002, grazing was managed using the put-and-take method, where calves were added as needed to maintain equal grazing pressure among pastures as described by Sollenberger and Burns (2001). During the fall, 90 steers (BW = 213 ± 2.7 kg) were placed on pasture on 13, 29, and 21 November for CT, RT, and NT, respectively, using a stocking rate of 3.75 steer ha^{-1} for the fall grazing period. For the graze-out phase in 2003, a total of 167 steers (BW = 259 ± 4.4 kg) were placed on pasture in three groups. An initial stocking of 45 steers (3 per pasture) were placed on pastures on

Table 1. Effect of tillage system on average grazing initiation and termination dates for steers grazing small-grain pastures during the fall and spring grazing periods.

Establishment method	Grazing initiation	Grazing termination	Grazing-days
Fall, 2002–2003			
Conventional tillage	13 Nov.	28 Jan.	76
Reduced tillage	29 Nov.	28 Jan.	60
No till	21 Nov.	28 Jan.	68
Spring, 2003			
Conventional tillage	27 Feb.	5 May	66
Reduced tillage	25 Feb.	6 May	69
No till	25 Feb.	5 May	68
Fall, 2003–2004			
Conventional tillage	28 Oct.	23 Jan.	87
Reduced tillage	28 Oct.	23 Jan.	87
No till	28 Oct.	23 Jan.	87
Spring, 2004			
Conventional tillage	2 Mar.	27 Apr.	56
Reduced tillage	2 Mar.	27 Apr.	56
No till	2 Mar.	27 Apr.	56
Fall, 2004–2005			
Conventional tillage	3 Dec.	28 Jan.	56
Reduced tillage	6 Dec.	28 Jan.	53
No till	16 Nov.	28 Jan.	73
Spring, 2005			
Conventional tillage	9 Mar.	1 May	53
Reduced tillage	9 Mar.	7 May	59
No till	9 Mar.	9 May	61
Fall, 2005–2006			
Conventional tillage	18 Nov.	16 Feb.	90
Reduced tillage	18 Nov.	16 Feb.	90
No till	18 Nov.	16 Feb.	90
Spring, 2006			
Conventional tillage	3 Mar.	28 Apr.	56
Reduced tillage	6 Mar.	28 Apr.	59
No till	6 Mar.	28 Apr.	59

31 January, while a second group of 68 steers was added on 17 March and a third group was added in mid-April in an attempt to equalize forage allowance among pastures, with a targeted forage allowance of 0.20 to 0.24 kg DM kg BW^{-1} and forage mass of 1243 to 1339 kg ha^{-1} (Redmon et al., 1995).

The stocking rates during the subsequent grazing studies were set based on forage allowance estimated from rising plate data. In the fall of 2003, 90 steers (BW = 208 ± 2.2 kg) were assigned to pastures on 28 October at a stocking rate of 3.75 steer ha^{-1}. During the fall of 2004, 60 steers (BW = 220 ± 5.7 kg) were assigned to pasture on 3 December, 6 December, and 16 November for CT, RT, and NT, respectively, at a stocking rate of 2.5 steer ha^{-1}. In the fall of 2005, 60 steers (BW = 233 ± 6.2 kg) were assigned to pastures on 18 November at a stocking rate of 2.5 steer ha^{-1}.

In the spring of 2004, 135 steers (BW = 233 ± 2.5 kg) were assigned to pasture on 2 March at a stocking rate of 5.63 steers ha^{-1} and removed on 27 April. In the spring of 2005, 135 steers (BW = 226 ± 3.4 kg) were assigned to treatment pastures on 9 March, at a stocking density of 5.63 steers ha^{-1}. In the spring of 2006, a total of 180 (BW = 240 ± 2.9) steers were utilized. The initial stocking consisted of 9 steers per pasture, which were placed on treatment pastures between 28 February and 8 March. Three steers were then added to all treatment pastures on 12 March.

Table 2. Precipitation and average daily temperature at the research site during four small-grain growing seasons.

Year	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May
Precipitation					mm				
2002–2003	80	47	46	197	37	136	34	56	259
2003–2004	92	60	147	109	50	51	106	204	140
2004–2005	1	212	207	68	104	62	106	109	132
2005–2006	132	0	68	15	98	49	118	120	107
30-yr average†	87	98	134	110	80	81	111	116	119
Average daily temp.					°C				
2002–2003	25	16	10	7	3	5	11	18	21
2003–2004	20	17	12	5	2	4	12	8	21
2004–2005	23	18	11	5	6	7	9	15	18
2005–2006	24	14	11	3	7	3	12	18	19
30-yr avg.†	22	15	9	4	2	4	9	14	20

† 30-yr average 1976 to 2006.

Statistical Analysis

Animal BW, average daily gain (ADG), BW gain, grazing-d ha^{-1}, and BW gain ha^{-1} were analyzed as a completely randomized design using the mixed procedure of SAS (SAS Institute, 1991); pasture within tillage treatment by year was used as the random statement. In the presence of a year × treatment interaction ($P < 0.05$), data were analyzed by year using pasture within treatment as the random statement and the variance components option was used as the covariance structure. Least-squares means were separated using nonorthogonal single df contrasts to test the (i) effect of NT vs. varying levels of tillage (i.e., NT vs. CT and RT) and (ii) RT vs. CT. Treatment differences were considered significant with a P-value of ≤ 0.05.

Forage mass prediction equations for the rising plate data were generated using the regression procedure of SAS using the clipping data for each collection period. Forage DM mass ha^{-1} and forage nutritive value were analyzed as a repeated measure using the mixed models procedure of SAS; in the presence of a significant year × tillage treatment × sampling date effect ($P < 0.01$), least squares means were analyzed by year and least-squares means were separated using the predicted differences option of SAS.

RESULTS AND DISCUSSION

Forage Production

In the fall of 2003 (September, October, November, and December), precipitation (Table 2) was near 30-yr average levels, but was below 30-yr average during the late winter 2004 (January, February, and March). Average daily temperatures (Table 2) were near to slightly above 30-yr average throughout the grazing season. At the initiation of the 2003 fall grazing period in October, there was no difference ($P \geq 0.17$) in forage DM accumulation among treatments (mean = 1696 ± 103.4 kg DM ha^{-1}). At the end of the fall grazing period of 2004 (January), CT pastures had less ($P < 0.01$) forage than NT and RT pastures, which did not differ ($P = 0.15$; 1017, 1678, and 1466 ± 103.4 kg DM ha^{-1}, respectively). At the initiation of the 2004 graze-out in March, NT pastures had more forage ($P < 0.01$) than CT and RT pastures, while RT tended ($P = 0.06$) to have more forage than CT (1082, 1658, and1,360 ± 103.4 kg DM ha^{-1} for CT, NT, and RT, respectively). At the end of the 2004 graze-out phase in April, CT pastures had less ($P < 0.03$) forage than NT and RT pastures, which did not differ ($P = 0.53$), averaging 1428, 1845, and1753 ± 103.4 kg DM ha^{-1} for CT, NT, and RT, respectively.

During the fall of 2004, only a trace (1 mm) of precipitation (Table 2) was recorded following planting in September but precipitation levels were above 30-yr average during October, November, and January; average daily temperatures were above 30-yr average for all months during the study except May. For the 2004–2005 grazing season, forage accumulation did not differ ($P \geq 0.18$) among tillage treatments in October (overall mean 658 ± 212.8 kg DM ha^{-1}). In November, forage DM for NT pastures (1649 ± 212.8 kg DM ha^{-1}) was greater ($P < 0.01$) than RT (663 ± 212.8 kg DM ha^{-1}); forage production of CT (1149 ± 212.8 kg DM ha^{-1}) was intermediate and did not differ ($P = 0.11$) from NT or RT. In December, CT pastures had more forage than RT ($P = 0.01$); NT was intermediate and did not differ ($P \geq 0.16$) from the other treatments; averages were 2050, 1691, and 1269 ± 212.8 kg DM ha^{-1} for CT, NT, and RT, respectively. There were no differences ($P \geq 0.28$) in forage mass in January, February, March, and April, which averaged 1145, 816, 1653, 2790 ± 212.8 kg DM ha^{-1}, respectively. At the end of the spring grazing period in May, NT pastures had more ($P < 0.01$) forage than RT and CT pastures, while residual forage was greater ($P < 0.01$) in RT than CT, averaging 2895, 4295, 5228 ± 212.8 kg DM ha^{-1} for CT, NT, and RT, respectively.

In the fall of 2005, precipitation during September was greater than 30-yr average precipitation, while no precipitation was recorded in October and below 30-yr average precipitation was observed in November and December. In the 2005–2006 grazing season, there was no difference ($P \geq 0.61$) in forage mass among tillage systems during October and November, which averaged 1256 and 2789 ± 177.3 kg DM ha^{-1}, respectively. In December, NT pastures (2848 ± 177.3 kg DM ha^{-1}) contained more ($P \leq 0.05$) forage than CT (2341 ± 177.3 kg DM ha^{-1}) or RT (2323 ± 177.3 kg DM ha^{-1}) pastures. In January, CT pastures contained more ($P < 0.01$) forage than RT or NT pastures, which did not differ ($P = 0.11$), averaging 3751, 2465, 2868 ± 177.3 kg DM ha^{-1} for CT, RT, and NT, respectively. There were no differences ($P \geq 0.21$) among tillage treatments in forage mass in February (overall mean 2485 ± 177.3 kg DM ha^{-1}). In March, NT pastures (2589 ± 177.3 kg DM ha^{-1}) contained less ($P < 0.01$) forage than CT (3537 ± 177.3 kg DM ha^{-1}) and RT (3319 ± 177.3 kg DM ha^{-1}) pastures, which did not differ ($P = 0.39$). In April, RT and CT pastures contained more ($P < 0.01$) forage that NT pastures and RT tended ($P = 0.08$) to have more residual forage mass than CT pastures, averaging 4412, 3570, 4848 ± 177.3 kg DM ha^{-1} for CT, NT, and RT, respectively.

The forage mass data from this study indicate that conservation tillage techniques produce adequate forage for stocker cattle production. These results conflict with Wiatrak et al. (2004) and Soon et al. (2001) who reported that wheat forage production was greater for CT than NT pastures. However, the results of the current study agree with results of Halvorson et al. (2002) who indicated that tillage does not affect wheat forage yields in a study that compared different conservation tillage techniques with CT.

Forage Nutritive Value

In 2003–2004, there were significant effects ($P \leq 0.04$) of tillage treatment, month, and tillage treatment × month for CP, NDF, and IVOMD. Treatment and month effects were significant ($P \leq 0.01$) for ADF, but there was no interaction ($P = 0.18$) of these effects. In October and March, CP was not affected ($P \geq 0.18$) by tillage treatment, average of 325 and 201 ± 8.3 g kg^{-1}. While in January, CT (131 ± 8.3 g kg^{-1}) pastures contained less ($P \leq 0.01$) CP than RT (171 g kg^{-1}) or NT (160 g kg^{-1}). In April, CP content of NT pastures (105 ± 8.3 g kg^{-1}) was less ($P \leq 0.01$) than CT (142 g kg^{-1}) and RT (135 g kg^{-1}). The NDF concentration was not affected ($P \geq 0.08$) by tillage treatment in October, averaging 450 ± 15.7 g kg^{-1}. In January and March, NDF was less ($P \leq 0.05$) for CT (536 and 531 ± 15.7 g kg^{-1}, respectively) than RT (622 and 596 g kg^{-1}) and NT (618 and 590 g kg^{-1}). In April, NDF concentration of NT (682 ± 15.7 g kg^{-1}) pasture was greater ($P \leq 0.02$) than CT (614 g kg^{-1}) or RT (629 g kg^{-1}). Across the 2003–2004 grazing study, ADF concentrations of CT pastures (285 ± 8.3 g kg^{-1}) were less than RT (313 g kg^{-1}) or NT (314 g kg^{-1}). From October to November, ADF increased ($P < 0.01$) from 202 to 337 ± 9.5 g kg^{-1}. The ADF concentration decreased ($P = 0.02$) from January to March (322 ± 9.5 g kg^{-1}) with the initiation of spring growth, yet increased to 355 ± 9.5 g kg^{-1} in April with increased plant maturity. In October and January, IVOMD did not differ ($P \geq 0.15$) among tillage treatments, average of 844 and 726 ± 23.5 g kg^{-1}, respectively. In March, IVOMD of CT (853 ± 20.3 g kg^{-1}) was greater ($P = 0.01$) than NT (763 g kg^{-1}). In April, IVOMD was not affected ($P \geq 0.11$) by tillage treatment, averaging 782 ± 20.3 g kg^{-1}.

In 2004–2005, there were significant effects ($P \leq 0.02$) of tillage treatment, month, and tillage treatment × month for CP, ADF, and IVOMD concentrations. The effects of tillage treatment and month were significant for NDF, but there was no interaction ($P = 0.10$). Crude protein was not affected ($P \geq 0.07$) by tillage treatment in October, averaging 358 ± 10.6 g kg^{-1}. In November and December, CP content of RT (300 and 248 ± 10.6 g kg^{-1}) and NT (300 and 220 ± 10.6 g kg^{-1}) was less than CT (336 and 278 ± 10.6 g kg^{-1}) while in January CP content of RT (318 ± 10.6 g kg^{-1}) was greater ($P < 0.01$) than CT (255 g kg^{-1}) and NT (268 g kg^{-1}). The CP contents of the forage collected in February and April were greater ($P < 0.01$) for RT than CT, but NT was intermediate and did not differ from RT or CT, averaging 258 and 142, 307 and 210, and 280 and 198 ± 10.6 g kg^{-1} for CT, RT, and NT in February and April, respectively. In March and May, CP of forage sampled did not differ ($P \geq 0.13$) due to tillage system, averaging 268 and 123 ± 10.6 g kg^{-1}, respectively. The NDF content was greater ($P < 0.01$) in NT than CT and RT across the study, averaging 506, 490, and 483 ± 5.1 g kg^{-1}, respectively. The concentration of NDF decreased ($P < 0.01$) from 481 ± 8.4 g kg^{-1} in October to 411 g kg^{-1} in December, and then increased ($P < 0.01$) to 502 and 511 g kg^{-1} in January and February. With the initiation of spring re-growth in March NDF decreased to 441 ± 8.4 g kg^{-1}, then increased ($P \leq 0.04$) with increasing maturity in April and May. Acid detergent fiber was not affected ($P \geq 0.13$) by tillage system in October and November, averaging 228 and 217 ± 8.4 g kg^{-1}, respectively. In December, ADF concentration was greater ($P < 0.01$) in NT (232 ± 8.4 g kg^{-1}) than CT (174 g kg^{-1}) and RT (185 g kg^{-1}), while in January ADF did not differ ($P = 0.44$) for NT (261 ± 8.4 g kg^{-1}) and CT (289 g kg^{-1}) pastures, but were greater ($P < 0.01$) than RT (188 g kg^{-1}). In February, ADF was greater ($P < 0.01$)

in CT (247 ± 8.4 g kg^{-1}) than RT (188 g kg^{-1}), while NT (220 g kg^{-1}) was intermediate and did not differ ($P \geq 0.09$) from either. Acid detergent fiber was not affected ($P \geq 0.15$) by tillage system in March, April, or May, averaging 198, 303, and 338 ± 8.4 g kg^{-1}, respectively. In October and November, IVOMD was not affected ($P \geq 0.09$) by tillage system, averaging 824 and 864 ± 20.0 g kg^{-1}, respectively. In December and January, IVOMD of NT (782 ± 20.0 g kg^{-1}) was less ($P < 0.01$) than CT (867 g kg^{-1}) and RT (876 g kg^{-1}), while in February digestibility of CT (783 ± 20.0 g kg^{-1}) was less ($P < 0.01$) than RT (855 g kg^{-1}). In March, April, and May IVOMD was not affected by tillage system, averaging 860, 713, and 658 ± 20.0 g kg^{-1}, respectively.

In 2005–2006, there were significant effects ($P \leq 0.02$) of tillage treatment, month, and tillage treatment × month for CP concentration. Crude protein was not affected ($P \geq 0.16$) by tillage treatment in October, November, or December, averaging 283, 285, and 234 ± 8.7 g kg^{-1}, respectively. In January, CP content of CT was greater ($P < 0.01$) than RT and NT. In February, CP was less ($P \leq 0.05$) for RT than NT and CT, which did not differ ($P = 0.93$). During March and April, forage CP content did not differ ($P \geq 0.30$) due to tillage treatment, averaging 207 and 123 ± 5.1 g kg^{-1}, respectively. The effect of month was significant ($P \leq 0.01$) for NDF and ADF concentration, but there was no effect ($P \geq 0.10$) of tillage treatment or treatment × month. The NDF remained constant ($P = 0.34$) during October and November, averaging 418 and 427 ± 7.0 g kg^{-1}, respectively. The NDF content increased ($P < 0.01$) from November to December but again remained constant ($P \geq 0.56$) during December, January, and February, averaging 465, 466, and 460 ± 8.1 g kg^{-1}, respectively. With increasing maturity, NDF content increased ($P < 0.01$) from February through May. The ADF was greater ($P = 0.03$) in December than in November, but remained constant ($P \geq 0.06$) from November to February. The ADF increased ($P = 0.04$) from 201 ± 8.7 g kg^{-1} in February to 260 and 372 g kg^{-1} in March and April, respectively. The effects of tillage treatment and month were significant ($P \leq 0.02$) for IVOMD, yet there was no tillage treatment × month interaction ($P = 0.13$). Across sampling dates, IVOMD of RT was less ($P \leq 0.02$) than CT and NT, which did not differ ($P = 0.73$), averaging 767, 794, and 790 ± 6.9 g kg^{-1}, respectively. The IVOMD did not differ ($P = 0.71$) in October and November, averaging 865, and 870 ± 10.5 g kg^{-1}, respectively. In January, IVOMD decreased ($P = 0.02$) to 721 ± 10.5 g kg^{-1} then increased through February and March, averaging 791 and 826 g kg^{-1}, respectively. With increased maturity and fiber content IVOMD decreased ($P < 0.01$) to 581 ± 10.5 g kg^{-1} in April.

Although changes were observed in CP and IVOMD over the months of the grazing studies, it should be pointed out that digestibility and protein content were greater than animal requirements for a 250-kg steer to gain body weight in excess of 1.20 kg d^{-1} (70% total digestible nutrients and 12.4% CP; National Research Council, 1996) until the end of the spring grazing season in late April or early May of each year. This indicates that small-grain forage provides a nutrient-dense diet for grazing cattle and any differences in animal performance among establishment methods would likely be due to restrictions in forage availability.

Animal Production

Fall and Winter Grazing Period

In 2002, precipitation (Table 2) was less than 30-yr average levels during September, October, November, January, March, and April and was above 30-yr average during December, February, and May; while average daily temperatures (Table 2) were close to 30-yr average during the grazing season. Steers were removed from all pastures on 28 January for a total of 76, 60, and 68 grazing days for CT, RT, and NT, respectively (Table 1). Tillage system did not affect ($P \geq 0.34$) BW at the end of fall grazing or total BW gain ($P \geq 0.13$). Average daily gain was 0.21 kg greater ($P = 0.02$) for steers grazing RT than CT; however, NT was intermediate and did not differ ($P = 0.77$) from CT and RT.

During the fall and winter of 2003 to 2004, steers grazed pastures for a total of 87 d (Table 1). At the end of the fall grazing period, BW, total BW gain, and ADG (Table 3) of steers grazing NT were 17, 15.4, and 0.17 kg, respectively, greater ($P = 0.01$) than CT and RT, while CT and RT did not differ ($P \geq 0.85$).

Theoretically, the ability to conserve soil moisture during the summer months before planting should be a distinct advantage for the NT system. This proved to be true, because during the 2004–2005 fall grazing season steers grazed CT, RT, and NT for a total of 56, 53, and 73 d, respectively (Table 1). At the end of the fall grazing period of 2004–2005, there were no differences ($P \geq 0.19$) in BW (Table 3) among tillage systems, while total BW gain of steers grazing NT pastures was 12 kg greater ($P = 0.01$) than RT and CT. The ADG (Table 3) of steers grazing NT tended ($P = 0.09$) to be 0.12 greater than CT and RT, which did not differ ($P = 0.53$).

Even with the low rainfall totals during the fall of 2005 (Table 2), steers grazed pastures a total of 90 d (Table 1). At the end of the fall grazing period of 2005–2006, BW, total BW gain, and ADG of the steers averaged 342 ± 7.4, 108.7 ± 4.5, and 1.21 ± 0.05 kg, respectively, and did not differ ($P \geq 0.45$) by tillage method.

Spring Grazing Period

During the spring grazing phase of 2003, the respective average grazing days for CT, RT, and NT were 66, 69, and 68 d (Table 1). At the end of the spring grazing period of 2003, animal BW and total BW gain (Table 3) of RT steers was 21 and 14.5 kg, respectively, greater ($P \leq 0.04$) than CT. The ADG (Table 3) of steers grazing RT tended ($P = 0.06$) to be 0.18 kg greater than CT steers. Animal BW at the end of the spring grazing period 2003, total BW gain, and ADG of NT steers did not differ ($P \geq 0.78$) from CT and RT. In the spring of 2004, steers grazed pastures for a total of 56 d (Table 1). At the end of the spring grazing period of 2004, BW, total BW gain, and ADG (Table 3) did not differ ($P \geq 0.38$) among tillage systems.

In the spring of 2005, steers grazed CT, RT, and NT pastures for an average of 56, 59, and 59 d, respectively (Table 1). Steer BW at the end of the spring 2005 grazing period was not affected ($P \geq 0.16$) by tillage system, but total BW gain of steers grazing RT was 14.3 kg greater ($P = 0.01$) than CT. Average daily gain during the spring of 2005 did not differ among tillage systems ($P \geq 0.12$).

Table 3. Effect of tillage system on body weight (BW) and average daily gain (ADG) of steers grazing small-grain pastures during the fall and spring grazing periods.

Establishment method	Initial BW	Off pasture BW	BW gain	ADG
	kg steer^{-1}			kg steer^{-1} d^{-1}
Fall, 2002–2003				
No till	213	272	59.5	0.92
Conventional tillage	211	277	66.1	0.84
Reduced tillage	216	276	59.5	1.05
SE†	2.7	3.7	3.06	0.062
Contrast‡	$P > F$			
1	0.75	0.34	0.37	0.77
2	0.18	0.79	0.13	0.02
Spring, 2003				
No till	257	330	72.2	1.02
Conventional tillage	257	320	63.1	0.91
Reduced tillage	263	341	77.6	1.09
SE†	4.4	8.4	5.81	0.077
Contrast‡	$P > F$			
1	0.63	0.95	0.78	0.85
2	0.19	0.03	0.04	0.06
Fall, 2003–2004				
No till	210	266	56.8	0.65
Conventional tillage	207	248	41.2	0.47
Reduced tillage	208	249	41.5	0.48
SE†	2.23	5.3	4.55	0.052
Contrast‡	$P > F$			
1	0.45	0.01	0.01	0.01
2	0.73	0.85	0.96	0.96
Spring, 2004				
No till	236	297	61.2	1.09
Conventional tillage	231	293	61.9	1.11
Reduced tillage	231	293	62.4	1.11
SE†	2.5	3.4	2.16	0.039
Contrast‡	$P > F$			
1	0.14	0.38	0.72	0.72
2	0.79	0.92	0.89	0.88
Fall, 2004–2005				
No till	215	281	66.7	0.90
Conventional tillage	222	272	50.3	0.75
Reduced tillage	225	266	41.5	0.80
SE†	5.7	7.4	6.16	0.057
Contrast‡	$P > F$			
1	0.22	0.19	0.01	0.09
2	0.70	0.59	0.32	0.53
Spring, 2005				
No till	226	285	59.0	1.00
Conventional tillage	229	277	48.3	0.90
Reduced tillage	224	287	62.6	1.03
SE†	3.7	4.5	3.84	0.056
Contrast‡	$P > F$			
1	0.95	0.56	0.46	0.60
2	0.28	0.16	0.01	0.12
Fall, 2005–2006				
No till	233	345	111.5	1.24
Conventional tillage	233	339	106.2	1.18
Reduced tillage	234	342	108.4	1.20
SE†	6.2	7.3	4.53	0.050
Contrast‡	$P > F$			
1	0.99	0.65	0.45	0.45
2	0.87	0.73	0.73	0.74
Spring, 2006				
No till	241	297	55.3	1.01
Conventional tillage	239	296	56.9	0.97
Reduced tillage	241	298	56.2	1.05
SE†	2.9	3.4	2.51	0.046
Contrast‡	$P > F$			
1	0.77	0.95	0.68	0.95
2	0.63	0.80	0.83	0.24

† Standard Error of treatment least-squares means, n = 5.

‡ Preplanned contrasts included: (1) no till vs. conventional tillage and reduced tillage; (2) conventional tillage vs. reduced tillage.

In the spring of 2006, steers grazed for an average of 56, 59, and 59 d for CT, RT, and NT, respectively (Table 1). At the end of the spring 2006 grazing period, BW, total BW gain, and ADG of the steers averaged 297 ± 3.4, 56.2 ± 2.5, 1.01 ± 0.046 kg, respectively, and did not differ ($P \geq 0.24$) by tillage method.

Total Grazing—d ha^{-1} and Gain ha^{-1}

During the 2002–2003 study, grazing-d ha^{-1} (Table 4) was 107 d greater ($P = 0.01$) for CT than RT, yet NT did not differ ($P = 0.81$) from CT and RT. Total BW gain ha^{-1} was not affected ($P \geq 0.42$) by tillage treatment averaging 514 ± 21.3 kg. The reduction in ADG and increase in grazing-d ha^{-1} observed for CT compared with RT indicate that visual appraisal of forage allowance was not adequate for the tillage systems in this study. For this reason, identical stocking rates were used for all tillage system pastures and rising plate meters were used to estimate forage mass for subsequent years in the study.

During the 2003–2004 study, grazing-d ha^{-1} (Table 4) were identical (634 animal days) for all pastures during the study and could not be compared statistically. Total BW gain ha^{-1} (Table 4) was 52 kg greater ($P = 0.05$) for NT than RT and CT, while CT and RT did not differ ($P = 0.89$). During the 2004–2005 study, pastures established by NT produced 46 more ($P = 0.05$) grazing-d ha^{-1} (Table 4) than CT and RT, which did not differ ($P = 0.97$). Total BW gain ha^{-1} during

Table 4. Effect of tillage system on grazing-d ha^{-1} and gain ha^{-1} of small-grain pastures.†

Establishment method	Grazing-d ha^{-1}	Gain ha^{-1}
2002–2003		
No till	569	513
Conventional tillage	630	529
Reduced tillage	523	500
SE‡	25.8	21.3
Contrast§	$P > F$	
1	0.81	0.42
2	0.01	0.57
2003–2004		
No till	634	551
Conventional tillage	634	497
Reduced tillage	634	500
SE‡	–	19.6
Contrast§	$P > F$	
1	–	0.05
2	–	0.89
2004–2005		
No till	510	493
Conventional tillage	464	393
Reduced tillage	464	451
SE‡	16.9	32.1
Contrast§	$P > F$	
1	0.05	0.10
2	0.97	0.23
2005–2006		
No till	625	708
Conventional tillage	654	719
Reduced tillage	618	713
SE‡	10.2	25.8
Contrast§	$P > F$	
1	0.39	0.81
2	0.03	0.89

† Grazing seasons were fall 2002 to spring 2003, fall 2003 to spring 2004, fall 2004 to spring 2005, and fall 2005 to spring 2006.

‡ Standard Error of treatment least-squares means, n = 5.

§ Preplanned contrasts included: (1) No till vs. Conventional tillage and Reduced tillage, (2) Conventional tillage vs. Reduced tillage.

2004–2005 (Table 4) tended ($P = 0.10$) to be 69 kg greater for NT than CT and RT, while RT did not differ ($P = 0.23$) from CT.

During the 2005–2006 study, pastures established by CT produced 36 more ($P = 0.03$) grazing-d ha^{-1} (Table 4) than RT, while NT was intermediate and did not differ ($P = 0.39$). Total BW gain ha^{-1} (Table 4) did not differ ($P \geq 0.81$) due to tillage treatment, averaging 713 ± 25.8 kg ha^{-1}.

The ADG and gain per ha in this experiment were somewhat greater than values reported by Bertrand and Dunavin (1983) when comparing NT and CT for the production of a cool-season forage mixture consisting of rye, ryegrass, and crimson clover. These authors reported that cattle on NT pastures gained an average of 0.73 kg per day and cattle grazing CT pasture had average daily gains of 0.68 kg when grazed from mid-December to early May.

Differences in forage production and animal performance from year to year and among tillage systems may be explained by differences in environmental conditions. Environmental conditions affect small-grain forage yields from year to year (Henry and Gallaher, 1993). Uncertainty of forage production occurs because of inadequate soil moisture for stand establishment in the fall, as observed in the fall of 2004 (Table 2). The ability to conserve moisture during the summer months before planting was a distinct advantage for the NT system, which produced more forage in November 2004, thereby allowing cattle to be placed on pasture earlier than the other treatments. An economic analysis reported by Beck et al. (2005) indicates that forage production in the fall is a primary limiting factor in profitability of stocker cattle programs because value of BW gain averaged \$1.39 kg^{-1} for fall and winter grazing and \$0.52 kg^{-1} for spring grazing based on Arkansas market prices for the 10-yr period from 1991 to 2000. Clary and Rouquette (2004) compared the profitability of purchasing calves in the fall or spring for the spring grazing period. These researchers found that purchasing calves in the fall for spring grazing was more profitable than waiting to purchase these calves in the spring, even though this would require considerable feed expenses. Conservation tillage practices that can reduce weather-related risks for stand establishment and forage production should have built-in economic advantages for stocker cattle producers.

CONCLUSIONS

Tillage system had an impact on animal performance in this study; during the fall forage, growth was limited by lack of timely rainfall. In this experiment, NT establishment of small-grain forages for stocker calves was superior to CT and RT practices when fall rains are delayed and soil water profile can be maintained by summer chemical fallow. Establishment of small-grain pasture with conservation-tillage techniques was as successful as CT practices when timely fall rains promoted emergence and growth in all systems.

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